

## **PISTON PUMP HAVING CYLINDER WITH LEAK OPENING**

### **CROSS-REFERENCE TO RELATED APPLICATIONS**

**[0001]** This application claims the benefit of U.S. Provisional Application No. 60/446,322 filed on February 6, 2003.

### **STATEMENT OF FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT**

**[0002]** Not applicable.

### **BACKGROUND OF THE INVENTION**

**[0003]** This invention relates to piston pumps, and more particularly to high pressure or vacuum pumps with improved restarting capabilities.

**[0004]** Certain pumping applications require the pump to operate in on-off cycles. In high pressure or vacuum applications, on the order of 100 psi or more, the volume of air in working chamber(s) of the pump cylinder(s) can impede reciprocation of the piston(s) significantly such that restarting the pump requires a large amount of torque. This trapped air can tax the pump drive motor excessively and cause premature motor wear, difficult, inconsistent and failed restarting, and/or require expensive motors having higher starting torque.

**[0005]** There have been many attempts to make restarting easier or more consistent. One technique is to use a larger motor that is significantly oversized for normal operation, but which would provide high starting torque sufficient to overcome the resistance of the trapped cylinder air. Another, significantly more efficient technique is to create a leak path at the intake port (or exhaust port when pulling a vacuum) in the valve plate of the pump. This can be done by ramping an interior surface of the valve plate at the intake port such that the flapper valve controlling flow through the port does not fully seat and close off the intake port until after a threshold cylinder pressure is reached. This technique allows a relatively low-torque (and thus less expensive) drive motor to be used. However, it

requires rather expensive and time consuming machining of the valve plate to form the ramp. It can also fatigue the flapper valve at the intake and significantly reduce the flow rate of the exhausted air flow, which may be unsuitable for certain applications requiring specific or minimum flow rates.

**[0006]** Accordingly, a high pressure/vacuum pump with improved restarting capabilities is needed.

#### SUMMARY OF THE INVENTION

**[0007]** The present invention provides a piston pump having a housing defining an internal cavity in which is disposed a cylinder defining a cylindrical passage in which a head of a piston reciprocates to vary the volume of a working chamber of the cylinder. The cylinder has a leak opening providing communication between the working chamber and an ambient atmospheric pressure during at least a portion of a piston stroke.

**[0008]** The leak opening is located such that it is between the piston head and the valve head for the majority of the piston stroke. Preferably, the leak opening has a centerline lying in a plane intersecting the shaft axis and the centerline of the cylinder, preferably parallel to the shaft axis and perpendicular to the cylinder centerline. The leak opening is further located proximate to a top end of the cylinder within a spacing of less than about 0.2 inches, more preferably its center is about 0.05 inches from the top end of the cylinder. The piston head includes a seal slideably mating with an inner diameter of the cylinder. The center of the leak opening should be located no more than about 0.1 inches, preferably at about 0.05 inches, below the piston cup seal when the piston is at top dead center so that the piston cup traverses the opening and temporarily closes it near top dead center.

**[0009]** The leak opening may be sized differently and may be located at more or less distance from the top end of the cylinder for different sized cylinders. The size and location of the leak opening is generally independent of the piston stroke. Generally, increasing the leak opening increases the restart reliability and decreases

the flow rate of the pump and locating the leak opening further from the top of the cylinder (and thus the piston seal at top dead center) decreases the restart reliability and increases flow rate. However, regardless of cylinder size the leak opening should be of a similar order of magnitude in size and should be located nearer the top end of the cylinder than the bottom end.

**[0010]** The pump of the present invention having the leak opening in the cylinder provides for bleeding of working gas from the cylinder to the exterior of the cylinder. The bleeding is intermittent in that the preferred location of the leak opening is such that the piston cup passes from below to above the leak opening at each stroke to top dead center. This intermittent bleeding is such that, during transient off periods of the pump, the cylinder can be sufficiently depressurized to allow rapid restarting of the pump with a relatively low torque drive motor. Moreover, the leak opening can be a simple through bore formed by a quick and low-cost boring operation.

**[0011]** The present invention thus provides a pump having high restart reliability particularly suited for high pressure or vacuum on-off cycled applications. The improved restarting capabilities of the pump is provided by a simple boring operation without the need for expensive machining operations. Since the leak path is located in the cylinder at the proper location, flow rate losses are reduced as is valve fatigue.

**[0012]** The foregoing and other objects and advantages of the invention will appear from the following description. In this description reference is made to the accompanying drawings which form a part hereof and in which there is shown by way of illustration a preferred embodiment of the invention. This embodiment does not necessarily represent the full scope of the invention, however, and reference must be made therefore to the claims for interpreting the scope of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0013]** FIG. 1 is a cut-away side view of a piston pump according to the present invention with a housing cover removed to show internal components thereof;

**[0014]** FIG. 2 is a partial cross-sectional view taken along line 2-2 showing a piston in a cylinder of the pump near the beginning of the stroke; and

**[0015]** FIG. 3 is a view similar to FIG. 2 showing the piston at top dead center.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

**[0016]** Figures 1 and 2 shows a single cylinder high pressure/vacuum piston pump 10 with improved restarting capabilities according to the present invention. The pump 10 generally includes a housing 12 mounting a motor 14 with a rotatable drive shaft 16 extending along a shaft axis 17 into a crank chamber 18 in the housing 12. The shaft 16 mounts a fan 20 and a connecting rod 22 of a piston 24 having an enlarged circular head 26 disposed in the interior of a cylinder 28 inside the housing 12 so as to be generally perpendicular to the shaft 16, that is the shaft axis 17 is essentially perpendicular to a centerline 29 of the cylinder 28. A piston cup seal 30 is captured between the head 26 and a retainer 32. The piston cup seal 30 is sized to slideably seal against the inner diameter of the cylinder 28 as the piston 24 is reciprocated up and down by rotation of the shaft 16. A valve plate 34 having suitable intake and exhaust valves (not shown) controlled by thin metal flapper valves (not shown) is mounted to a top side of the housing 12 and sealed against a top end 36 of the cylinder 28. A valve head 38 mounts onto the valve plate 34 and has intake 40 and exhaust 42 fittings for coupling intake and exhaust lines (not shown) as needed for the desired application.

**[0017]** As shown in FIGS. 1-3, a leak opening 44, preferably a simple bore, extends transversely through the wall of the cylinder 28 providing communication between the interior of the cylinder 28 and the interior of the housing 12. The leak opening 44 is located near the top end 36 of the cylinder 28 such that it is

positioned between the piston 24 and the valve plate 34 during most, in fact, nearly all, of the piston stroke as shown in FIG. 2. In a preferred location, the leak opening 44 is positioned so its centerline 45 lies in a plane containing the shaft axis 17 as well as the centerline 29 of the cylinder 28, being parallel to the shaft axis 17 and perpendicular to the cylinder centerline 29. The leak opening 44 is also preferably positioned so that the piston cup seal 30 is below it except for as the piston 24 nears top dead center (i.e., its highest position) as shown in FIG. 3 at which point the piston cup 30 passes beyond the leak opening 44 and closes communication to the working chamber. In this way, the leak opening 44 is at the working side of the piston head 26 the majority of the time and is at the non-working side of the piston head 26 only while at or very near top dead center. Put another way, the leak opening 44 is above the piston head 26 when the crank angle is approximately between 10 to 350 degrees. This allows the leak opening 44 to bleed the working air out of the cylinder 28 during nearly the entire piston stroke. Yet, the leaking or bleeding is intermittent in that there is no leakage for the crank angles at or near top dead center.

**[0018]** The leak opening 44 is relatively small (compared to the volume of the cylinder 28) so that during steady state operation of the pump 10 at higher speeds, sufficient pressure or vacuum can be achieved to provide high flow rates. Yet, when the pump 10 is de-energized or operating at low speed like when starting up, the leak opening 44 will allow the working air in the cylinder 28 to bleed rapidly out the cylinder 28 so that the reciprocation of the piston 24 is less impeded, thereby allowing restarting with a low-torque motor. And, since the leak opening 44 is at the working side of the piston 24 for most of its stroke, when the pump 10 is stopped the piston cup 30 will most likely be below the leak opening 44 allowing bleeding of the compressed air in the cylinder 28 to prepare for the next restart. Moreover, when the pump 10 is stopped and piston 24 ceases being driven by the motor, the residual working air in the cylinder 28 acts to force the piston 24 down to at or near bottom dead center. This makes it even more likely that the leak opening 44 would be in communication with the working chamber of the cylinder 28. Thus,

the leak opening 44 will consistently provide the necessary bleeding function to ensure consistent restarting of the pump, even when using a low-torque motor.

**[0019]** In one preferred application, the pump 10 uses a low-torque motor providing 8 oz.-ft of starting torque and the pump 10 provides approximately 0.5 CFM output flow rate at about 60 psi. The cylinder 28 has a 2.25 inch inner diameter and 0.125 inch wall thickness. The piston stroke is about 0.32 inches. In this case, the leak opening 44 is preferably no more than about 0.1 inches in diameter, more preferably about 0.05 inches in diameter. The leak opening 44 is preferably located within about 0.5 inches of the top end 36 of the cylinder 28, more preferably at less than about 0.2 inches from the top end 36, and no more than about 0.1 inches, preferably at about 0.05 inches, below the piston cup seal 30 when the piston 24 is at top dead center. The above dimensions are taken from the horizontal centerline of the leak opening 44.

**[0020]** It should be noted that this is only one example of a preferred pump application. The leak opening 44 may be sized differently and may be located at more or less distance from the top end 36 of the cylinder 28 for different sized cylinders, operating pressures and/or flow rate requirements. Regardless of these parameters, the leak opening 44 should be of a similar order of magnitude in size and should be located nearer the top end of the cylinder than the opposite (bottom) end.

**[0021]** As mentioned, the leak opening 44 is aligned with the drive shaft axis 17, which has been found to provide the greatest flow rate (roughly 25% higher than a leak opening positioned perpendicular to the shaft axis). It has also been determined empirically that, while increasing restart reliability, putting the leak opening 44 lower (further away from the top of the cylinder 28 and the piston cup seal 30 at top dead center) significantly decreases the output flow rate of the pump. Generally, the leak opening 44 location is independent of piston stroke. The diameter of the leak opening 44 can vary depending on the flow requirements of the application, preferably keeping a minimum diameter to prevent debris from clogging

the leak opening 44. Generally, increasing the diameter of the leak opening 44 will improve the restart reliability but decrease the flow rate of the pump.

**[0022]** An illustrative embodiment of the invention has been described in detail for the purpose of disclosing a practical, operative structure whereby the invention may be practiced advantageously. However, the apparatus described is intended to be illustrative only, and the novel characteristics of the invention may be incorporated in other structural forms without departing from the scope of the invention. For example, the precise size and location of the leak opening can vary depending on flow rate and pressure requirements of the application. Moreover, while only a single leak opening is described above and shown herein, it is within the scope of the invention for the cylinder to have multiple leak openings at various locations in the cylinder. Additionally, while a 60 psi application was been described, the improvement in restart reliability and flow rate can be realized in higher pressure or vacuum applications of 100 psi or more. Accordingly, to apprise the public of the full scope of the invention, the following claims are made: